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Environmental Engineering (EE); Requirements and use cases of liquid cooling and high energy efficiency solutions for 5G BBU in C-RAN mode

Reference

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Foreword

This final draft ETSI Standard (ES) has been produced by ETSI Technical Committee Environmental Engineering (EE), and is now submitted for the ETSI Membership Approval Procedure.

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Executive summary

Liquid cooling systems are mainly used for processing capability of the high thermal power density, which exceeds the physical limits of air cooling methods, to support more and more application scenarios where manufacturers are creating competitive advantages. Liquid cooling can provide heat transfer capabilities several orders of magnitude higher than that of air cooling, and applications dealing with high heat density in the core and edge computing as well as access network will increasingly require the support of liquid cooling technology.

The present document identifies the requirements for liquid cooling and high energy efficiency solutions for 5G BBU in Centralized-RAN mode, including requirements of immersion and spray liquid cooling technology, key indicators of immersion and spray liquid, safety requirements of immersion and spray liquid cooling system, management procedure and energy efficiency measurement method, and use cases of liquid cooling solutions.

Introduction

The power consumption of 5G BBU increases significantly compared with that of 4G BBU. On the one side, in Centralized-RAN mode, BBU is centrally installed in the cabinet, and the number of BBU in one cabinet can reach as many as 10. Besides, in the air cooling system of the BBU, the airflow goes in from the left side and out from the right side (or in from the right side and out from the left side). All of the factors mentioned above make it difficult to dissipate the heat generated from BBU, resulting in a significant increase in air conditioning cooling capacity and power consumption required for heat dissipation of BBU equipment compared with the 4G one. On the other side, the internal stability of the equipment becomes poor and the failure rate increases because the internal temperature of the BBU is too high. From the perspective of equipment safety as well as energy saving and carbon reduction, exploring more efficient and energy-saving technical methods is crucial. In order to solve the heat dissipation problem of 5G BBU in Centralized-RAN mode, it is necessary to introduce liquid cooling technology to provide a better heat dissipation effect for equipment with high power density and complex airflow conditions.

Liquids have a much larger thermal capacity than that of gases, which makes them ideal as heat dissipation media in high-density devices, and therefore liquid cooling has been already heavily used in the server cooling of data centres. In the liquid cooling system, there is no compressor, instead, it can directly use the heat dissipation of outdoor air as a natural cold source. The CoolEff of the liquid cooling server has been proved to be reduced to 1.1-1.2 practically. Though the entire power of BBU is less than that of the server, the volume power density is higher compared with that of the server, which makes it suitable to utilize liquid cooling. This recommendation focuses on the solution of liquid cooling method being used in the 5G BBU.

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5. It is published respectively by ITU and ETSI as Recommendation ITU-T L.1326 [i.1] and ETSI ES 203 997 (the present document), which are technically-equivalent.

1 Scope

The present document provides requirements for liquid cooling and high energy efficiency solutions for 5G BBU in Centralized RAN mode (C-RAN), including: requirements of immersion and spray liquid cooling technology, key indicators of immersion and spray liquid, safety requirements of immersion and spray liquid cooling system, management procedure and energy efficiency measurement method, and use cases of cooling solutions.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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[i.1] Recommendation ITU-T L.1326 (08/2023): "Requirements and use cases of liquid cooling solutions and high energy efficiency solutions for 5G BBU in Centralized-RAN mode".

[i.2] ETSI TS 103 586: "Environmental Engineering (EE); Liquid cooling solutions for Information and Communication Technology (ICT) infrastructure equipment".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

Cloud RAN (C-RAN): Radio Access Network (RAN) where functions are partially or completely centralized, with two additional key features: pooling of baseband/hardware resources, and virtualization through general-purpose processors

Distributed RAN (D-RAN): network development where Radio Access Network (RAN) processing is fully performed at the site, as in 4G

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

4G	fourth Generation
5G	fifth Generation
AHU	Air Handling Unit
BBU	BaseBand Unit
CDU	Coolant Distribution Unit
CoolEff	Cooling Effectiveness
CPU	Central Processing Unit
CRAC	Computer Room Air Conditioner
GSM	Global System for Mobile communications
GTMU	GSM Transmission & Timing & Management Unit
GWP	Global Warming Potential
ICT	Information and Communications Technology
IT	Information Technology
ODP	Ozone Depletion Potential
PCB	Printed Circuit Board
RAN	Radio Access Network
UPEU	Universal Power and Environment interface Unit
UPS	Uninterruptible Power Supply

4 Description of the cooling solutions

In the past few years, the air cooling system makes it possible to accommodate higher heat density cooling requirements by bringing the cold source closer to the heat source or by hot-aisle/cold-aisle containment. However, as rack power density increases to above 20 kW (Figure 1), the benefits of these methods gradually diminish. A variety of liquid cooling technologies have emerged to meet the cooling requirements of high heat density cabinets.

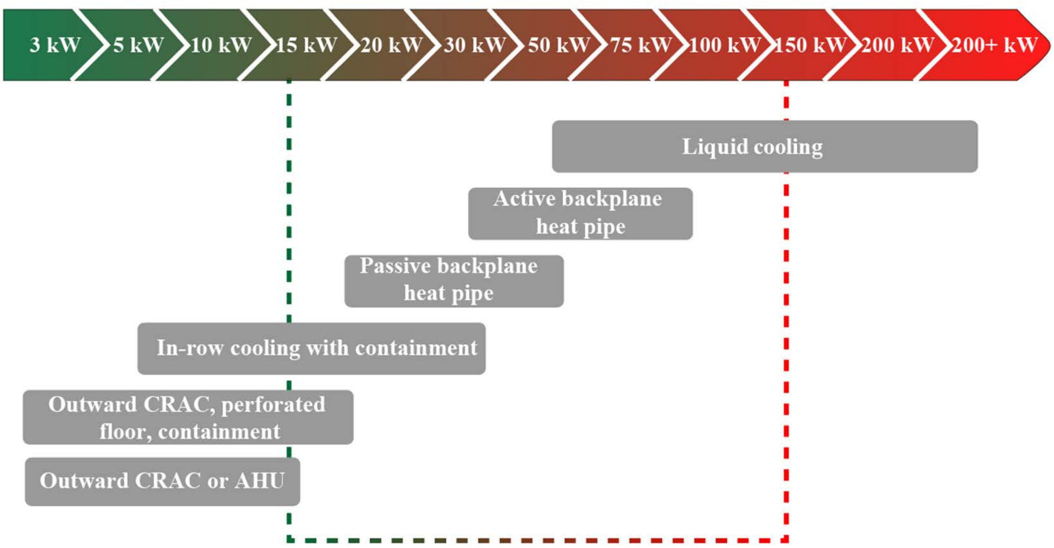

Figure 1: Rack power density and cooling solutions

5G BBU is deployed in the cabinet in Centralized-RAN mode, which not only has a large total power (10 BBUs reach 5-6 kW), but also because the BBU air flow sometimes is insufficient, which makes it difficult to cool the cabinet.

The traditional cooling mode in data centre is not suitable for the cooling demand of 5G BBU in Centralized-RAN mode. The BBU equipment with liquid spray can cool the BBU chip/board with high density and the main board without relying on any air flow channel.

Using immersion and spray liquid cooling technology can not only solve the problem of low energy efficiency for 5G base station (BBU centralized deployment-the C-RAN mode), but also solve the problem of high density of BBU chip and difficulty of heat dissipation. However, as a new technology completely different from the traditional air cooling technology, it needs a complete system design and safety protection mechanism; otherwise unexpected safety risks may appear and damage the whole system.

5 Immersion and spray liquid cooling technology

5.0 General

Nowadays, there are three main types of liquid cooling technology for ICT equipment, i.e. liquid cooling of cold plates, immersion, and spray. The configuration of different parts in 5G BBU is extremely dense and the overall dimension of the 5G BBU device is 2 u high, containing 4 layers of BBU board with each board about 2 cm thick, and the gap between one board and the other is not more than 5 mm. The typical configuration of the BBU is shown in Figure 2. The corresponding slots of the BBU are listed in Table 1. And therefore neither pasting the heat exchange plate on the heat-generating chip of the board nor adding liquid flow copper tubes on the PCB board is feasible. Based on the factors mentioned above, the 5G BBU can only utilize immersion or spray liquid cooling methods other than cold plate liquid cooling.

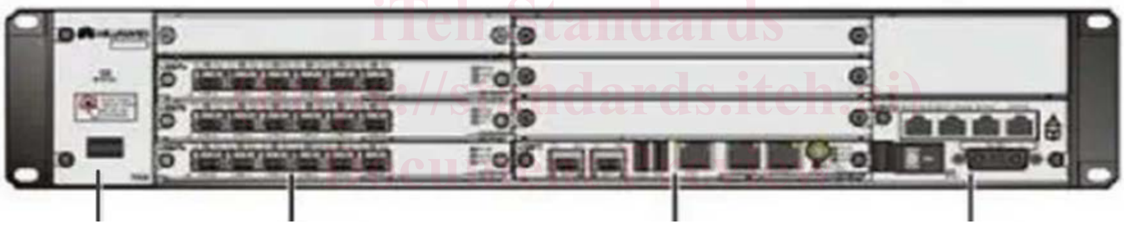

Figure 2: Typical Configuration of the BBU

Table 1: Slots of the BBU

FAN	Slot 0	Slot 4	Power
	Slot 1	Slot 5	
	Slot 2	Slot 6	Power
	Slot 3 (Baseband board)	Slot 7	

5.1 Immersion liquid cooling

In an immersion liquid cooling solution, all BBU components are immersed in a flowing thermally conductive and electrically insulating liquid. By this method, the flowing liquid takes away the heat generated by all BBU components, which maximizes the heat conduction characteristics of the coolant and is the most energy-efficient liquid cooling method. In a single-phase immersion liquid cooling system, the entire BBU device is installed vertically with the front side up in the thermally conductive and electrically insulating coolant. The coolant is in direct contact with all BBU components and absorbs heat from them, after which the coolant is carried by a pump to a heat exchanger in the CDU (coolant distribution unit). Inside the heat exchanger, the heat is transferred between the refrigerant and the coolant resulting in temperature decreases of the coolant, after which the low-temperature coolant can participate in the next circulation of heat absorption of BBU components and heat release in the heat exchanger in the CDU. As for the heat absorbed by the refrigerant, it can finally be taken to the outdoor heat dissipation equipment through the heat exchanger in the CDU. The detailed coolant circulation and heat transfer in single-phase immersion liquid cooling systems are demonstrated in Figure 3. CDU is usually installed near the BBU device cabinet or outside the data centre room.

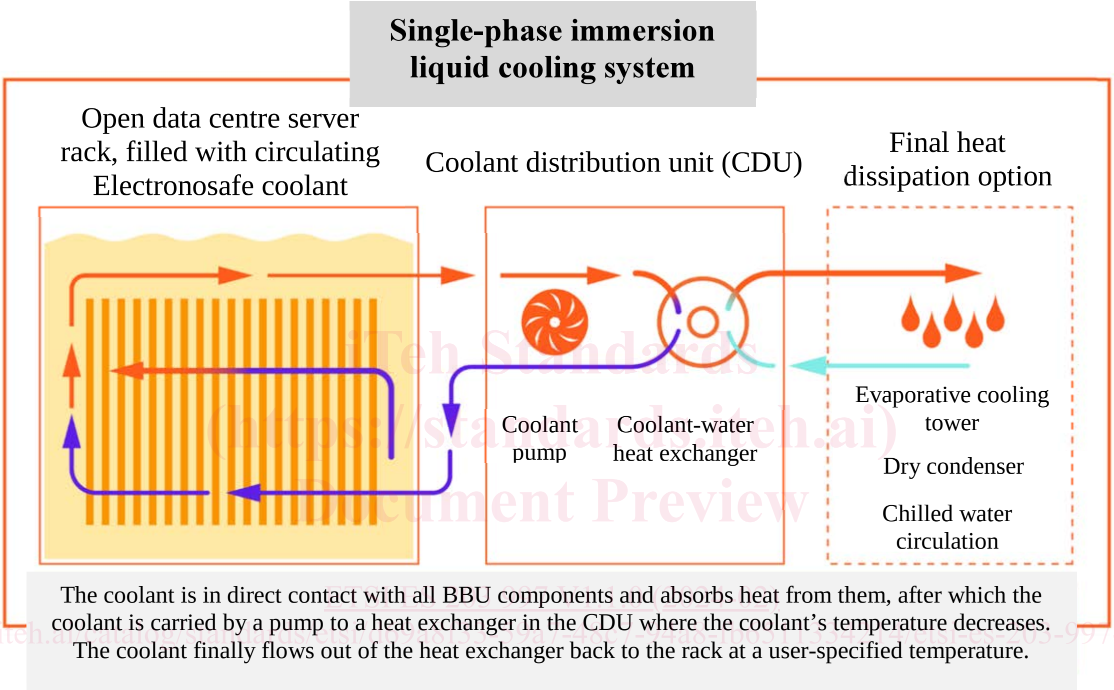

Figure 3: Coolant circulation and heat transfer in single-phase immersion liquid cooling systems

An image of the immersion liquid cooling cabinet is presented in Figure 4. Immersion liquid cooling cabinets usually use horizontal sink cabinets with one cabinet holding 10 BBU devices, and each BBU device holds 6 baseband boards at most. When immersion liquid cooling is used, the fan module of BBU can be saved. In order to facilitate the usual installation and maintenance of BBU devices, all the BBU devices are inserted vertically and the front panel faces upwards and is exposed above the liquid level (some components of the front panel are expected to be in the liquid), so that the upper half of the optical module on the front panel is not soaked in the liquid, minimizing the risk of contamination of the surfaces of the optical module core plug by the liquid. Most immersion liquid cooling uses single-phase fluorinated liquids, which are liquid phases both in the endothermic and exothermic processes, with extremely small liquid volatilization, and there is no need to consider the sealing property of the horizontal cabinet, and the disadvantage is that the heat dissipation capacity is not as much as the gas-liquid phase.

There are several important parameters of the immersion liquid cooling BBU devices to be considered, including overall dimensions, inside dimension of the liquid storage reservoir, available space, the number of BBU devices, BBU device thermal dissipation solution, liquid supply pump redundancy mechanism, maximum heat-dissipation power of one cabinet, cold source, liquid cooling device power supply mode, and annualized CoolEff.

Next, some requirements shall be considered within the important parameters to ensure effective immersion liquid cooling for BBU devices, the requirements are discussed as follows:

a) Overall Dimensions (L×W×H): Specify the required dimensions of the immersion liquid cooling system, including length (L), width (W), and height (H), to ensure compatibility with the designated space and equipment layout.

b) Inside Dimension of the Liquid Storage Reservoir (l×w×h): Determine the dimensions of the liquid storage reservoir, specifying its length (l), width (w), and height (h) to accommodate the required volume of immersion liquid while allowing sufficient space for proper circulation and cooling.

c) Available Space: Assess the available space for installing the immersion liquid cooling system, considering factors such as cabinet layout, equipment placement, and any potential constraints or restrictions.

d) Number of BBU Devices: Determine the total number of BBU devices that need to be cooled using the immersion liquid cooling system to ensure adequate capacity and performance.

e) Liquid Supply Pump Redundancy Mechanism: Implement a redundancy mechanism for the liquid supply pump(s) to ensure uninterrupted cooling in case of pump failure or maintenance requirements. This can involve redundant pumps, backup power supply, or alternative cooling solutions.

f) Maximum Heat-Dissipation Power of One Cabinet: Determine the maximum heat-dissipation power that a single cabinet can handle to ensure the immersion liquid cooling system can effectively dissipate the generated heat from the BBU devices. This information helps determine the cooling capacity required for the system.

g) Cold Source: Identify a reliable and efficient cold source to maintain the immersion liquid at the desired temperature. This could involve refrigeration units, chillers, or other cooling technologies depending on the scale and requirements of the installation.

h) Liquid Cooling Device Power Supply Mode: Specify the power supply mode for the liquid cooling devices, such as direct electrical connection or the use of an Uninterruptible Power Supply (UPS), to ensure continuous operation and minimize potential downtime.

i) Annualized CoolEff: Assess the annualized Cooling Efficiency of the immersion liquid cooling system, which indicates the system's effectiveness in cooling the BBU devices while optimizing energy consumption. This parameter helps evaluate the overall efficiency and sustainability of the cooling solution.

By considering these important parameters, effective design, installation, and operation of an immersion liquid cooling system for BBU devices can be ensured.

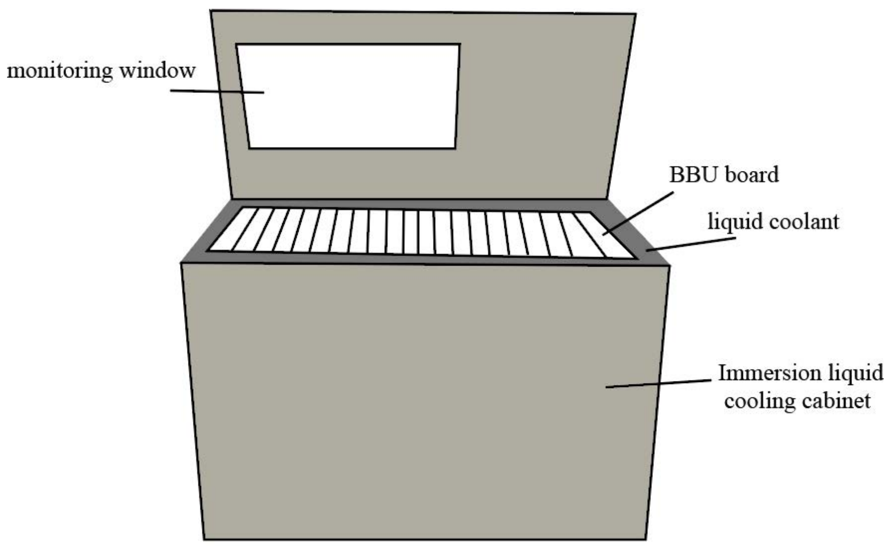

Figure 4: An image of the immersion liquid cooling cabinet